NanoFab's General Overview for

Electron Beam Lithography Resists

The NanoFab has two EBL systems, the Raith 150 and the Leo 440. The following EBL resist general overview will discuss choosing an EBL resist, the EBL spinner, the standard processes that are used in EBL, and measuring the thickness of EBL resist using the Single Wavelength Ellipsometer.

Choosing an EBL Resist

The first step in EBL is developing a process and a process flow chart. After this, a pattern can be designed and created and the pattern will either be transferred/written into a positive PMMA resist or a negative SU-8 resist.

<u>PMMA Positive Resist</u>

- PMMA (polymethyl methacrylate) is a positive polymer resist.
- http://www.microchem.com/products/pmma.htm
- The NanoFab has two different types of PMMA resists, PMMA 950K A2 and PMMA 495K A2.
    - The 950K and the 495K refers to the molecular weight i.e. the length, of the PMMA chains.
        - The 495K is composed of smaller chains of PMMA and is more sensitive and than the 950K formula.
        - Note: The higher the molecular weight, the better the contrast between exposed and unexposed regions.
    - The A stands for the solvent anisole, which is better for the environment than the chlorobenzene solvent.
    - The 2 indicates that the solvent contains 2% PMMA by weight percent solvents.
- Longer polymer chains typically dissolve slower in solvents than shorter polymer chains. During exposure, polymer chains undergo scission (cutting) enabling them to dissolve easier into the developer than the longer and unexposed chains.

SU-8 2000 Negative Resist

- This is an epoxy based resist that has high resolution and contrast.
- It is a chemically amplified negative resist; therefore it does not need a high dose during exposure.
    - When SU-8 2000 is exposed, strong acids are formed in the exposed areas.
    - A post-exposure bake activates the areas that the strong acids initialized, resulting in epoxy cross-linking.
- SU-8 is difficult to remove due to the extreme epoxy cross-linking, so typically SU-8 remains and becomes a feature.
- More info at http://www.microchem.com/products/su_eight.htm

The HeadWay Resist Spinner

- The HeadWay Resist Spinner is a manual resist dispense system, typically used for EBL resists.
- The spinner is in a fumehood, which enables various organic chemistries to be used, and has a wafer chuck that holds 1 cm by 1 cm dies.
- This spinner also allows the spread and spin speeds, the ramp rate, and the times to be changed for each different experiment.
    - RPM is the speed in revolutions per minute, RAMP is how long it takes to get to that speed, and TIME is how long it remains at that speed.

Standard EBL Processes

There are three standard EBL processes at the NanoFab, single layer PMMA, bilayer PMMA, and single layer SU-8.

PMMA Processing

- PMMA is positive resist, therefore the resist that is exposed by the electron beam is removed after developing.
- In the single layer PMMA process, typically a single layer of PMMA 950K is spun onto the substrate and exposed, as shown in Fig 1a).
- In the bilayer PMMA process, a layer of PMMA 495K is spun on the substrate first, followed by a layer of PMMA 950K.
    - Because PMMA 495K is more sensitive than 950K, when the substrate is exposed to electron beam, the bottom layer will be more undercut than the top layer as shown in Fig 1b).
    - This enables more PMMA surface area to be exposed which results in improved lift off.

Figure 1 a) single layer PMMA process and b) bilayer PMMA process. Because the bottom 495 K layer is more sensitive in the bilayer process, a larger area is developed when compared to 950K layer.

Substrate PMMA 950K PMMA 495K

- After the PMMA is patterned, it can either be used as a permanent feature on the substrate, or is can be used as a mask for deposition.
- Typically a metal is deposited on the substrate using ebeam evaporation and then the substrate is placed in an ultrasonic acetone bath, which lifts off or removes the PMMA resist as shown in Fig 2.
    - Ebeam evaporation is used because there is less sidewall coverage when compared to sputtering and the chamber does not typically heat up enough to melt the resist.
        - The ultrasonic acetone bath enables the acetone to attack any exposed PMMA, lifting the PMMA and the metal covering the PMMA off.
        - Note that the deposition must be thinner than the thickness of the resist, or there will be no exposed PMMA to attack.

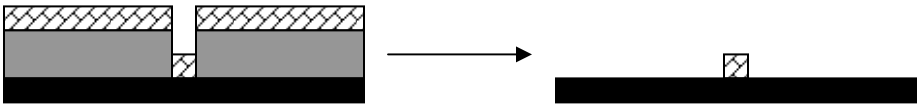

Figure 2 Chrome deposited on a patterned EBL die. After being exposed to acetone in an ultrasonic bath, the PMMA and chrome lifts on leaving only a pattern of chrome.

Substrate PMMA 950K Chrome

<u>SU-8 Processing</u>

- SU-8 is a negative resist, therefore the resist that is exposed to the electron beam remains after developing.
- Single layer SU-8 processing is done, where resist is spun, exposed and developed.
- Once the substrate is patterned with SU-8, it is very hard to remove and the SU-8 usually remains as a permanent feature on the wafer.

Single Wavelength Ellipsometer

- Monochromatic HeNe laser light with known wavelength and polarization is reflected on the surface.
- By analyzing the change in polarization of the reflected light, the optical constants and/or thickness of EBL resist may be determined.

NanoFab's Standard Operating Procedures for

Electron Beam Lithography Resists

The following standard operating procedures outlines the EBL resist spinning process. This process includes operating the HeadWay Resist Spinner, single and bilayer PMMA spinning, single layer SU-8 spinning, and operating the single wavelength ellipsometer.

Operating the HeadWay Resist Spinner

1. Get the PMMA bowl and wash the chuck with acetone/IPA.
2. Turn on the vacuum with the black knob. Note: Do not exceed 10 psi.
3. Turn on the HeadWay Resist Spinner using the switch at the back.
4. Click the CHG PRE button to change the presets on the system.
5. Make sure that Recipe 3 selected.
6. To move up and down the recipe press the +/- buttons.
7. To change a parameter press ENT and use the arrow (➡ ⬅) buttons to change to digit locations. The +/- buttons will increase/decrease the digit value.
8. When finished, press ENT and continue to scroll through and change the recipe.
9. To apply these changes, press the MSG button and start the spinner by pressing the START button.

A Sample Recipe

Spread
- RPM1 set to 100.
- Ramp1 set to 5.
- Time1 set to 10.
- RPM2 set to 100
- Ramp2 set to 0.
- Time2 set to 1

Spin
- RPM3 set to 4000.
- Ramp3 set to 15.
- Time3 set to 40.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).

Single Layer PMMA Process for Lift-Off

1. Piranha clean the Si dies and dehydration bake them on a contact hot plate for 5 minutes at 200^{o}C.
2. Spin PMMA 950 A2 @ 4000 rpm for 30 seconds. Films are about 90 nm thick.
3. Soft bake on a hotplate at 200^{o}C for 2 minutes to drive off the solvents.
4. Pattern with the LEO 440 or the Raith 150.
5. Developing
    a. Agitate in MIBK:IPA 1:3 for 45 seconds (developer).
        i. MIBK is methyl isobutyl keytone.
    b. Agitate in IPA for 15 seconds (stopper)
    c. Rinse with DI water.
    d. Dry and bake for 2 minutes on a hotplate.
6. Inspect with a microscope to ensure patterns have transferred.
7. Deposit metal by sputtering or evaporation.
8. Strip off the resist using an ultrasonic acetone bath or a suitable stripper.
9. Metal pattern is transferred.

Bilayer PMMA Process for Improved Lift Off

1. Piranha clean the Si dies and dehydration bake them on a contact hot plate for 5 minutes at 200^{o}C.
2. Spin PMMA 495 A2 @ 4000 rpm for 40 seconds. Films are about 170 nm thick.
3. Soft bake on the contact hot plate at 180^{o}C for 30 minutes.
4. Spin PMMA 950 A2 @ 4000 rpm for 40 seconds.
5. Bake on the contact hot plate at 180^{o}C for 30 minutes.
6. Pattern with the LEO 440 or the Raith 150.
7. Developing
    a. Agitate in MIBK:IPA 1:3 for 45 seconds (developer).
        i. MIBK is methyl isobutyl keytone.
    b. Agitate in IPA for 15 seconds (stopper)
    c. Rinse with DI water.
    d. Dry and bake for 2 minutes on a hotplate.
8. Optically inspect to ensure patterns have transferred.
9. Deposit metal by sputtering or evaporation.
10. Strip off the resist using an ultrasonic acetone bath or a suitable stripper.
11. Metal pattern is transferred.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).

Standard Process for Etch Resistant SU-8

1. Piranha clean the Si dies and dehydration bake them on a contact hot plate for 5 minutes at 200^{o}C.
2. Spin the SU-8 2000.1 @ 4000 rpm for 40 seconds. Films are about 150 nm thick. Softbake at 65^{o}C for 60 seconds and 120^{o}C for 120 seconds.
3. Exposure on the Leo 440 or Raith 150.
4. Post exposure bake the dies at 65^{o}C for 60 seconds and 95^{o}C for 60 seconds.
5. Developing
    a. Agitate in SU-8 Developer for 60 seconds (developer).
    b. Agitate in IPA for 10 seconds (stopper)
    c. Rinse with DI water.
    d. Dry and bake for 2 minutes on a hotplate.
6. Inspect with a microscope to ensure patterns have transferred.

Operating the Single Wavelength Ellipsometer

1. Turn on the key to the ellipsometer 30 minutes before use. This will turn on the laser and allow it to warm up properly.
2. Turn on the computer with the DOS Boot Disk in the A drive.
3. At the A:/ prompt, put in the 2WS disk and type 2WS then press Enter.
4. Select F2 (ENGG).
5. Select F2 (display).
6. Enter the sample number.
7. Select Option 1 (n and thickness).
8. The expected n is roughly 1.5 for PMMA.
9. Select F1 (red).
10. Enter incidence angle (70^{o}).
11. Enter expected thickness.
12. Enter n and k from GEN program (for substrate).
13. Push in the W and F filters on the ellipsometer.
    a. The Mode Switch on the analyzer should be on M (manual).
14. Place specimen under the laser beam.
15. Adjust the table height until there is a max reading on the LED screen.
16. The analyzer may have to be rotated it get the initial peak.
17. Look in the microscope and center the crosshairs and the X using the x and y table tilt.
18. The light reflected from the laser should be centered in the analyzer hole.
19. Switch the Mode Switch to A and the analyzer will spin.
20. Select F6 and the thickness will be measured.
21. The equation will give many different thicknesses, so make an educated guess to ensure the right thickness is chosen.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).

NanoFab's Quick Glance at

Electron Beam Lithography Resists

Operating the HeadWay Resist Spinner

1. Press the CHG PRE to change presets.
2. Select Recipe 3.
3. Use +/- buttons to move up and down.
4. To change a parameter, press ENT & use arrow (➡ ⬅) buttons to change digit locations. +/- increases or decreases digit value.
5. Press ENT and check the recipe.
6. Press MSG button to finish.
7. Start spinner by pressing START.

Single Layer PMMA Process for Lift-Off

1. Dehydration bake for 5 min @ 200^{o}C.
2. Spin PMMA 950K @ 4000 rpm for 30 s.
3. Soft bake @ 200^{o}C for 2 min.
4. Pattern with LEO 440 or the Raith 150.
5. Developing
    a. Agitate in MIBK:IPA 1:3 for 45s
    b. Agitate in IPA for 15 s
    c. Rinse with DI water
    d. Dry and bake for 2 min.
6. Inspect.
7. Deposit metal by sputtering or evaporation.
8. Lift off resist in ultrasonic acetone bath.
9. Metal pattern is transferred.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).

Bilayer PMMA Process for Improved Lift Off

1. Dehydration bake for 5 min @ 200°C.
2. Spin PMMA 495K @ 4000 rpm for 40 s.
3. Soft Bake @ 180°C for 30 min.
4. Spin PMMA 950K @ 4000 rpm for 40 s.
5. Bake @ 180°C for 30 min.
6. Pattern with the LEO 440 or the Raith 150.
7. Developing
    a. Agitate in MIBK:IPA 1:3 for 45 s
    b. Agitate in IPA for 15 s.
    c. Rinse with DI water.
    d. Dry and bake for 2 min.
8. Inspect.
9. Deposit metal by sputtering or evaporation.
10. Lift off resist with an ultrasonic acetone bath.
11. Metal pattern is transferred.

Standard Process for Etch Resistant SU-8

1. Dehydration bake for 5 min @ 200°C.
2. Spin SU-8 4000 rpm for 40 s.
3. Soft bake at 65°C for 60 s and 120°C for 120 s.
4. Exposure on the LEO 440 or Raith 150.
5. Post exposure bake: 65°C for 60 s and 95°C for 60 s.
6. Developing
    a. Agitate in SU-8 Developer for 60 s.
    b. Agitate in IPA for 10 s.
    c. Rinse with DI water.
    d. Dry and bake for 2 min
7. Inspect.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).

Operating the Single Wavelength Ellipsometer

1. Turn the key and let laser warm up for 30 minutes.
2. Install boot disk and get a:/ prompt.
3. Install 2WS disk and type 2WS then press enter.
4. Select F2 (Engg).
5. Select F2 (display).
6. Enter Sample #.
7. Select Option 1 (n and thickness).
8. Type in expected n (1.5 for PMMA).
9. Select F1 (red).
10. Enter incidence angle (70^{o}).
11. Enter expected thickness.
12. Enter n and k values for substrate.
13. Push in W and F filters and place sample under laser light.
14. Switch the mode switch to M.
15. Adjust table height until there is a max reading on the LED.
16. Look in the microscope and center the crosshairs and the X using the x/y table tilt. The laser should be centered in the analyzer hole.
17. Switch the mode switch to A.
18. Press F6 to measure and note the result.

Note: These processes are just guideline and should be optimized for each process and environment (temperature and humidity).